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13. ABSTRACT *(Maximum 200 words)*

The National Biodynamics Laboratory (NBDL) of the University of New Orleans has preserved recoverable indirect impact acceleration data from non-human primate subject tests performed by the former Naval Biodynamics Laboratory. Non-human primate subjects were exposed to frontal, rear, lateral and vertical acceleration forces from 3 to 192g.

Recovered data are classified as: Kinematic, Physiological, Medical, and Ancillary. Kinematic data consist of three subcategories: sensor-derived, photographic-derived, and 3-D trajectory data. Physiological data consist of pre- and post-impact cardiac (ECG), spinal cord somatosensory evoked potentials (SEP), and body temperature measurements. Pre- and post-impact medical and clinical examinations generate physiological, radiological, and blood chemistry data. Ancillary data consist of testing information originally collected in various formats.

Data quality has been thoroughly checked, errors corrected, all work documented, and a database logically organized containing data in good condition has been developed. All tables in the database are related, with primary, secondary and other keys clearly defined. Oracle® software has been used to implement the database and the querying mechanisms. This database has been incorporated into the National Crash Survival Data Bank (NCSDB), already housed at NBDL. NBDL serves as custodian, providing convenient access to the NCSDB for federal, military, academic and commercial users.

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FINAL TECHNICAL REPORT

GRANT #: N00014-00-1-0546

PRINCIPAL INVESTIGATOR: Dr. Thomas G. Dobie (e-mail: tdobie@uno.edu)

INSTITUTION: University of New Orleans, College of Engineering, National Biodynamics Laboratory

GRANT TITLE: Archiving and Databasing of Non-Human Primate Impact Data

AWARD PERIOD: 15 July 2000 - 30 November 2001

OBJECTIVE: Retrieval, preservation and archiving, data quality assessment, and databasing of all recoverable non-human primate subject impact acceleration data collected by the former Naval Biodynamics Laboratory and incorporating the recovered data into the National Crash Survival Data Bank (NCSDB) to complement the human impact acceleration test data already residing in the NCSDB, subject to ONR approval.

APPROACH: The National Biodynamics Laboratory (NBDL) of the University of New Orleans has preserved recoverable indirect impact acceleration data from non-human primate subject tests performed by the former Naval Biodynamics Laboratory. Non-human primate subjects were exposed to frontal, rear, lateral and vertical acceleration forces from 3 to 192g. Three chimpanzee subjects and 115 rhesus monkey subjects were utilized for these indirect impact tests in order to produce a body of impact data.

In addition, the laboratory has designed and built an object-relational database to provide worldwide data accessibility. The database developed under the Human and Manikin contract (N00014-98-1-0335), the National Crash Survival Data Bank (NCSDB), is housed permanently at NBDL on a computer network providing convenient access to federal, military, academic and commercial users, both nationally and worldwide. The National Biodynamics Laboratory serves as the custodian of the NCSDB. With the completion of this project, the NCSDB has been expanded by NBDL to include all recoverable rhesus monkey and chimpanzee impact data.

ACCOMPLISHMENTS: Recovered data are classified as: Kinematic, Physiological, Medical, and Ancillary. Kinematic data consist of three subcategories: sensor-derived data, photographic-derived data and EZFLOW (3-D trajectory) data. Sensor data represent digitized, scaled measurements derived from sensor instruments, such as linear accelerometers and angular velocimeters. Photographic data represent scaled, digitized photo target positional measurements from high-speed 16-mm cameras. The majority of impact tests were filmed by either two or three cameras. The third kinematic data type is processed 3-D trajectory data. The impact data analysis program (EZFLOW) computed the three-dimensional trajectory of selected anatomical segments of the experimental subject. Photo and sensor data have been analyzed in order to produce these data.

Physiological data consist of pre- and post-impact cardiac (ECG), spinal cord somatosensory evoked potentials (SEP), and body temperature measurements.

Medical data have been collected from various examinations performed on test subjects. Medical and clinical examinations generate physiological, radiological, and blood chemistry data. Pre- and post-impact clinical tests generate more medical history data.

Recovery of as much data as possible, with some effort dedicated to those data files that were not readily recovered, was a priority. Data quality has been thoroughly checked, errors corrected, all work documented, and a database logically organized containing data in good condition has been developed. All tables in the database are related, with primary, secondary and other keys clearly defined. Oracle® software has been used to implement the database and the querying mechanisms.

Kinematic Data: Of 389 animal subject impact acceleration tests, 30 tests were of a documentary nature, with no data collected except for 16-mm film from off-board cameras. Digital kinematic data were collected for the remaining 359 impact acceleration tests. These data had been stored in a variety of formats on multiple storage media, including magnetic tapes and cartridges, computer disk drives, and black–and-white and color 16-mm film. The validation and migration of all kinematic data from source media to final storage on magneto-optical disks has been completed. Backup sets are stored on CDs and archived in two separate locations.

Sensor Data: Sensor data sets consist of data from, or related to, measurements taken by piezoresistive linear accelerometers arranged in sensor arrays rigidly attached to the subject's head. Accelerometers were also mounted on the sled chair. All raw sensor data have been stored on the NCSDB Server and are also distributable via CD.
Digital inertial sensor data for 288 non-human primate impact tests have been validated and transferred to the NCSDB Server. All migrated data sets have been extensively reviewed and validated. All tapes (analog and digital) containing sensor data had to be cleaned before data could be retrieved. The quality of the digital data produced by the analog to digital (A/D) conversion has been checked and edited, if necessary. Header information fields detailing test setup parameters have been recreated and appended to these data files. The validation and transfer of these sensor data sets to the NCSDB Server has been completed.
A total of 292 data sets have been processed. The body of migrated data includes 27 sets of chimpanzee subject data in digital form. Each data set consists of digital sensor data, collected for multiple sensors on multiple anatomical mounts. The body of migrated data includes 261 sets of rhesus subject data in digital form. Each data set consists of digital sensor data, collected for multiple sensors on multiple anatomical mounts.

Photographic Data: Photographic data have been collected for 383 animal subject impact tests on 16-mm film. Of these 383 tests, 283 were digitized after the original tests were completed and stored off-line on magnetic tapes and on-line on a network of Hewlett-Packard 9000 series computers. In order to improve the quality of the digitized photo target data, 59 previously digitized high acceleration tests have been re-photodigitized under this project and saved. Previously digitized photo data for 194 of the other 224 tests have been saved and served as input to the PC data reduction program, in order to produce three-dimensional kinematic motion data. A total of 30 tests were originally filmed with off-board cameras for documentary purposes only, and yielded no photographic data. Data from the 59 re-digitized tests and the 283 previously identified digitized photo target data have been preserved to permanent storage. The photographic data have been converted from 16-mm film to digital form through a photodigitization process which provides 2D coordinates for each of the targets being tracked for one, two, or three cameras. The validation and transfer of historical photographic data from the original storage media to the NCSDB Server is complete. The validation and permanent storage of all re-digitized photographic data is complete. All migrated data sets have been extensively reviewed and validated. The body of photographic datasets includes 16 sets of chimpanzee subject data and 267 sets of rhesus subject data. Each set consists of digital photo target data, collected for several photo targets on multiple anatomical mounts, and for multiple camera sites.

Three-Dimensional Motion Data: These data are considered to be the most useful of all data being archived. These sets contain kinematic variables (linear and rotational displacements, velocities, and accelerations for the three spatial dimensions). A total of 336 sets of 3-D motion data have been generated and transferred to the NCSDB Server. A 3-D motion digital data set for each impact test contains over 40 files. Each file identifies an individual kinematic variable. All files, in unison, describe the 3-D motion of the test subject. An in-house Windows-based data reduction and analysis system, PC-EZFLOW, has been used to optimally generate the 3-D motion data sets. Sensor and photographic digital data, together with other ancillary data, serve as input to the PC-EZFLOW system. All migrated sensor and photographic impact data sets have been processed through the Windows-based PC-EZFLOW software system and saved on the NCSDB Server, resulting in 336 sets of 3-D motion data. A total of 222 data sets, previously residing on a Unix-based HP9000 system, were also migrated to the NCSDB Server. These 222 data sets are predominantly a subset of the 336 sets generated by the PC-EZFLOW software system. In order to generate the 3-D motion sets, raw sensor and photographic data were processed with the EZFLOW software to produce processed data in the anatomical coordinate system. All 3-D motion data sets have

been extensively reviewed and validated. The data were processed by PC-EZFLOW and the output logs saved to the Novell server. The body of 3-D motion data includes 27 chimpanzee subject digital sets and 309 rhesus subject digital sets. All 3-D motion data have undergone a final review for completeness and quality. The findings of this review have been concurrently entered into the NCSDB, and are to be used to identify data sets for distribution. The PC-EZFLOW software system is compatible with Windows 95/98/NT/2000 platforms and is available for custom generation of 3-D motion data sets.

Physiological Data: The original physiological data resided on 205 analog magnetic tapes. A total of 311 runs were digitized. All data have been entered in the NCSDB along with records of data acquisition parameters for each run that was originally recorded on paper only. A total of 311 runs with physiological data are available. A total of 3 chimpanzee test subjects and 115 rhesus test subjects participated in runs with physiological data. A total of 25 tests contain electrocardiogram (ECG) data for 3 chimpanzee subjects. Somatosensory evoked response (SEP) data for 2 chimpanzee subjects are contained in 8 tests. ECG data for 115 rhesus subjects are contained in 284 tests. A total of 174 tests have SEP data for 115 rhesus subjects.

Medical Data: A large set of medical records and data for the subjects have been entered into the NCSDB and converted to portable document format (PDF). Categories have been established for Medical Histories, Pathology Reports, and Ancillary Data. Medical history contains such information as NBDL clinical history, lab test results, dental procedures, immunizations, surgical reports, and x-rays. Pathology reports contain both the official and preliminary pathology data. Ancillary data indicate the availability of paper ECG and EEG strip charts, and identify all surgical procedures. Medical data have been archived for all 3 of the chimpanzee subjects and 115 of the 115 rhesus test subjects. In addition, data originally collected on medical forms have been scanned, converted to PDF format and incorporated into the NCSDB.

Ancillary Data: Ancillary information related to the impact acceleration test runs was originally collected in various forms and formats; some of these were found only in printouts or handwritten paper copies. All of these data have been scanned, converted to PDF format, and entered into the NCSDB. The following data have been archived: photo target surveys; sprocket hole data; photo digitizer data sheets; camera checklists; camera site surveys; camera calibration data; camera setup sequences; lab/camera transformation matrices; camera constants and nodal points; instrument mount listings; accelerometer calibration data; data acquisition system calibration (pre-run calibration summary); corrections to zero offsets for all accelerometers; run summary sheets (gray sheets); physiological analog data acquisition system data log; physiological analog data acquisition system run log; TEAC RD-200T 16 channel DAT setup data sheets; analog data acquisition system magnetic tape data log; analog data acquisition system FM multiplex channel identification log; and the analog data acquisition system physiological run logs for evoked response and ECG.

Data Quality Assessment: The condition of all the data has been evaluated before, during, and after archiving and databasing. Software has been modified to produce an automated, rigorous assessment package for kinematic and physiological data types of non-human primate impact tests. Quality checks to determine the condition of the data sets have been implemented, and errors documented and corrected where necessary and possible. Quality assessment of the data, as described above, has been completed using DADISP, a commercially available software program, also operable on Windows platforms.

Software Conversion: Prior to integration into the NCSDB, a proprietary program, EZFLOW, processed the impact data. EZFLOW has been extensively reprogrammed to operate on Windows95/98 NT/2000 platforms. The resulting program, PC-EZFLOW, has been modified to process non-human primate impact tests. A second proprietary program, the NBDL Impact Data Browser, has been created to allow users of the data to view and interact with data and is distributed free of charge to users of the NCSDB. The program can also be used to convert the data to ASCII files, which can be readily imported into other standard statistical software programs.

EZFLOW Data Reduction Program: Impact 3-D motion data sets are generated by the in-house data reduction system PC-EZFLOW, originally known as EZFLOW and written for a Unix system. This system of programs, previously resident on a network of Unix-based Hewlett Packard 9000 series computers, has

been successfully converted to operate under the Windows 95/98/NT/2000 platforms. The system consists of two major components: the photographic (photo) variables program and the sensor variables program. The photo variables program analyzes photographic data sets in order to produce a set of 3-D motion kinematic variables describing the motion of the test subject for the duration of the impact test. These photographic data sets are generated from the photodigitization of analog signals recorded by multiple camera sites during the impact test. In addition to the photographic data, other ancillary information serves as input to the photo variables program. The photo variables program has been successfully converted to operate under the Windows 95/98/NT/2000 platforms, and has been successfully modified to process non-human primate impact tests. The sensor variables program analyzes sensor data to produce a set of 3-D motion kinematic variables describing the motion of the test subject for the duration of the impact test. These sensor data sets, serving as input to the PC-EZFLOW sensor variables program, are generated from the digitization of analog signals recorded by multiple inertial sensors during an impact test. In addition to the sensor data, ancillary information serves as input to the sensor variables program. This information includes instrumentation sensor calibration and subject anatomical coordinate system transformation. The sensor variables program has been successfully converted to operate under the Windows 95/98/NT/2000 platforms, and has been successfully modified to process non-human primate impact tests. The PC-EZFLOW software system, a versatile data reduction and analysis tool, is able to analyze historical impact test data as well as afford customization for the analysis of future impact test data. The PC-EZFLOW program was used to process all animal subject sensor and photographic data sets to generate 3-D motion data sets for this project.

NBDL Impact Data Browser Program: The NBDL Impact Data Browser Program has been designed and implemented to view, convert, and store kinematic data. Version 1.1 of the Impact Browser is currently maintained. The Impact Browser is a visual, interactive MS-Windows-based application program, designed to be distributed with the kinematic data sets purchased by NCSDB users. The three categories of kinematic data available for analysis are sensor, photographic, and 3-D motion. Important program features include data export and graphical display capabilities. Time traces of kinematic variables of interest can be displayed individually, as well as grouped by functionality. Data may be converted to ASCII text format and saved to disk as needed. Detailed documentation of the Impact Browser will be made available to all users, and is available to other researchers on request.

Relational Database Development: The National Crash Survival Data Bank (NCSDB) is a collection of descriptive information about all the impact data, combined into a relational database. The NCSDB was originally created under the project entitled "Data Archiving, Conditioning, and Databasing of Impact Acceleration Test Data", performed under Cooperative Agreement N00014-98-1-0335. Currently, the NCSDB can only be searched via the Internet for human and anthropomorphic manikin impact data. With the completion of the, "Archiving and Databasing of Non-Human Primate Impact Data" project, the NCSDB has been expanded to incorporate non-human primate subject impact data. This makes the non-human primate data readily available in an organized manner, which can be searched to select data for subject kinematic as well as medical and physiological data. At this time access to the non-human primate test data is restricted and can only be accessed by NBDL. This matter is under consideration by ONR. The NCSDB querying (search) mechanism for human subjects is available online at http://www.nbdl.org

CONCLUSIONS: With the inclusion of non-human primate response to indirect impact, the already valuable NCSDB becomes even more valuable to the scientific community. Testing to acquire similar data cannot be accomplished in today's research environment due to funding limitations and restrictions on using non-human primates as research subjects. The NCSDB provides other researcher organizations data for validating models being developed for human tolerances for indirect impact, spinal injury potential, restraint systems, and crash scenarios.

SIGNIFICANCE: The recovered and preserved NCSDB data from non-human primates resulting from completion of this project represents a valuable resource to researchers seeking to refine biomechanics and injury models of response of the human body to indirect impact forces. The value of this resource is increased by magnitudes in light of the fact that similar impact tests using non-human primates are not likely to be performed today or in the near future due to funding limitations and the concerns of using animals in testing programs.

PATENT INFORMATION: Action has been taken to secure copyright of the NCSDB through the Library of Congress to protect NBDL's intellectual property rights.

AWARD INFORMATION: None

REFEREED PUBLICATIONS (for total award period): 1

Guccione, Jr., S. J. and Kaminsky, E., "Human Head-Neck Kinematic Response to Impact Acceleration: Comparison of Oblique to Combined Frontal and Lateral Response". Proceedings of the 17th International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, 2001

BOOK CHAPTERS, SUBMISSIONS, ABSTRACTS AND OTHER PUBLICATIONS (for total award period):

1. "Archiving and Databasing of Non-Human Primate Impact Data", Detailed Final Report, University of New Orleans, National Biodynamics Laboratory, November 30, 2001

Note: Several additional publications are planned once NBDL receives clarification from ONR of the restrictions on publication of non-human primate data.